



Remote Sensing as a Low Cost Tool in Regional Exploration of Limestone Deposits: A Case Study from Abay Basin (Blue Nile Basin), Ethiopia

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Abstract

The objective of the present article is to discuss the exploration approaches and its results, using remote sensing, related with exploration of limestone in an area of 140 sq. kms in the Abay Basin, Ethiopia. Based on remote sensing mapping, a field geological mapping program was planned and executed to verify and check it on ground level. During this field work sampling was carried out to collect the samples and analyze it for their geochemical properties. Based on these approaches in the initial phase of exploration three patches having good resource potential and quality of limestone were demarcated in the block. The analyzed samples of limestone showed good quality (CaO% – 50.74 - 55.14, SiO₂% – 0.17 - 4.73, MgO% – 0.06 - 0.80, phosphorus, iron oxide and alumina within 1%). The quality of limestone suggests that it can be utilized for manufacturing of steel and cement. The quality based reserves estimation indicated about 17.53 million tons of limestones in proved category within 20 meter depth from the surface. Remote sensing guided approaches led quite fast exploration works in the block with success in the discovery of good quantity and quality limestone, at a relatively low exploration cost, within short time duration.

Keywords: Stratigraphy, Limestone, Exploration, Remote sensing, Abay basin, Ethiopia.

Introduction

The Ketketo area of the Abay Basin comprises of the Mesozoic sedimentary sequence. The Mesozoic sequence which is about 600 m in thickness in the River Valley areas of the Ketketo consists of sedimentary rocks unconformably overlain by Tertiary volcanic (Gani et al. 2009). The area is structurally relatively simple; almost all the

sedimentary rocks are in their depositional position. The area of the Ketketo block is about 140 sq. kms. The location of the Ketketo Block is shown in Figure 1. The objective of this article is to discuss approaches and its results applied in exploration of Ketketo Block to find out commercial viable deposits of limestone for utilizing in steel and cement manufacturing.

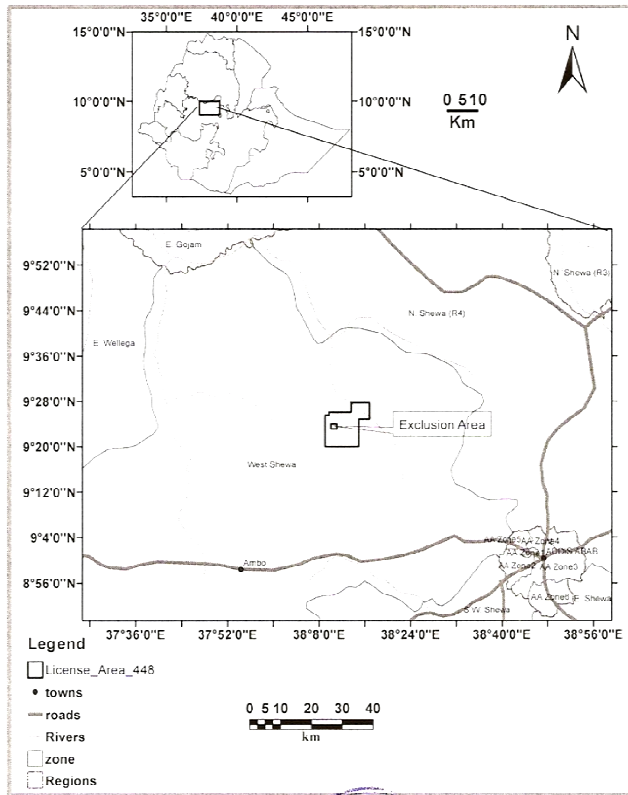


Fig. 1. Ketketo Limestone Block.

Geology of the Region

The stratigraphy of the Abay Basin, in ascending order, comprises Goha Tsion Formation, Antalo Limestone, Amba Aradom Formation and the Trap Series (Tertiary basalt). The regional geological mapping carried out in the Ketketo Block revealed the following lithologies: Soil, Basalt, and Limestone. The Antalo Limestone is very well exposed in the Ketketo Block area. Generally the limestone is light gray, occasionally yellowish, fractured and fossiliferous. Limestone present in the area has a total thickness of more than 200 mts. In many parts limestone has been weathered to clay as has been found in the geochemical analysis results. At present three patches, based on outcrop mapping and geochemical data, has been demarcated in the block having limestone either exposed at the surface and in some parts just covered below a thin layer of soil with good quality (Fig. 2). The strike of the

exposed limestone outcrops are in W-NW direction. The dip of the limestone outcrops is very gentle indicating less influence of tectonic activity.

Materials and Methods

Block area was demarcated on satellite imageries and lithological signatures were identified with respect to limestone, shale, basalt and soil. In a designed regional exploration methodology workflow, first a general stratigraphic framework of the region under investigation was determined. After this lithological association was determined and its specific imagery attributes were determined and analyzed using remote sensing analysis of satellite imageries data. The specific image attributes utilized are colour, tone, texture, shape, size, pattern, aggregate of attributes and colour filtration technique to identify and distinguish different lithology present in the region. Among rocks, limestones have relatively higher reflectance, thus appears relatively bright in colour and tone on satellite imageries. Based on these textural inputs potential areas were demarcated and selected field geological mapping and sampling programs. Samples were analyzed, to know the geochemical properties and quality of limestone, at the laboratory of Geological Survey of Ethiopia. Using these techniques the three patches were demarcated having good quality and potential good quantity of limestone.

Results and Discussion

The regional field geological mapping, utilizing satellite imageries inputs, carried out in the Ketketo Block revealed the following lithologies: Soil, Basalt, and Limestone. The Antalo Limestone is very well exposed in the Ketketo Block area. Generally the limestone is light gray to white, occasionally yellowish, fractured, due to weathering, and fossiliferous. Limestone present in

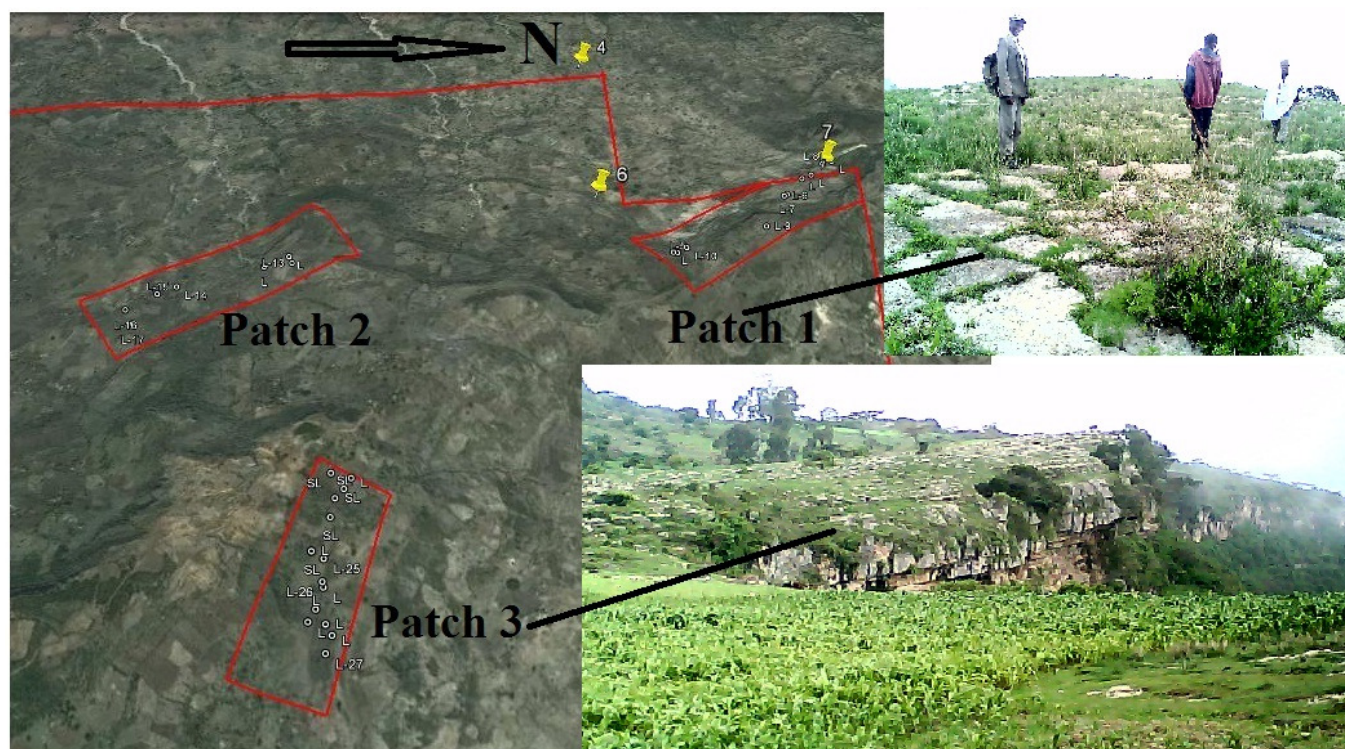


Fig. 2. Satellite imagery with demarcated Patches 1, 2 & 3 for field checks. Photo showing outcrops of limestone of Patch 1 & 3.

the area has a total thickness of more than 200 mts. In many parts limestone has been weathered to clay as has been found in the geochemical analysis results. Based on remotely sensed, field and geochemical data three patches were identified as given in **Figure 2**. Limestone, with good quality, is either exposed at the surface and in some parts just covered below a thin layer of soil. The strike of the exposed limestone outcrops are in W-NW direction. The dip of the limestone outcrops is very gentle indicating less influence of tectonic activity. Based on these investigations a surface geological map was also prepared of the whole Ketketo Block area (**Fig. 3**).

Geochemistry of Limestone

Analysis of the geochemical results indicates good quality for its utility in steel and cement manufacturing.

Patch 1 (Note – S.N. refers sample number)

Patch 1						
Geochemical Parameters	S. N. 5	S.N. 6	S.N. 7	S.N. 8	S.N. 9	S.N. 10
SiO ₂	2.75%	1.90%	2.03%	0.17%	0.65%	3.18%
CaO	53.34%	53.10%	53.42%	55.14%	53.84%	53.24%
MgO	0.36%	0.06%	0.34%	0.14%	0.54%	0.80%
Al ₂ O ₃	0.69%	1.01%	0.96%	0.16%	0.27%	0.51%
Fe ₂ O ₃	0.2	0.56%	0.66%	0.20%	0.24%	0.34%
Phosphorous	0.02%	0.01%	0.03%	0.01%	0.01	0.01%

Patch 2

Patch 2				
Geochemical Parameters	S.N. 14	S.N. 15	S.N. 16	S.N. 17
SiO ₂	4.73%	3.18%	1.55%	2.03%
CaO	50.74%	52.58%	53.30%	52.64%
MgO	0.80%	0.48%	0.50%	0.54%
Al ₂ O ₃	1.46%	1.06%	0.32%	0.59%
Fe ₂ O ₃	0.64%	0.50%	0.32%	0.74%
Phosphorous	0.05%	0.03%	0.01%	0.05%

Patch 3

Patch 3			
Geochemical Parameters	S.N. 25	S.N. 26	S.N. 27
SiO ₂	3.21%	1.75%	2.11%
CaO	51.22%	52.56%	52.26%
MgO	0.72%	0.32%	0.46%
Al ₂ O ₃	1.33%	0.51%	0.48%
Fe ₂ O ₃	0.52%	0.36%	0.20%
Phosphorous	0.01%	0.01%	0.01%

Resources and Reserves of Limestone

Integrating field geological mapping and geochemical data an evaluation has been carried out to determine the potential reserves and resources of these three patches.

Assumptions and Methodology

1. In reserves/resource determination, sampled points of outcrops, thickness of outcrops and their continuity and area of influence (200 meter) has been taken.
2. The unit of measurement provided here for length, width and thickness is in meters.
3. The thickness for reserve/resources determination has been considered taking into account those samples elevations whose quality is appropriate as per the geochemical analysis data and elevations of their nearby limestone outcrops where potential of continuity of similar quality seems quite high. However, only 20% of the total determined resources have been putted in potential Proved Reserve category. All remaining amount has been putted in the Probable and Possible Reserves.
4. Density of the limestone, for tonnage calculation, taken is 2.5.
5. With more exploration work these reserve may increase further in these patches as well as in other parts of the Block.

Tonnage = [Length×Width×Height (Thickness) ×Density]

Patch 1:

800×200×27×2.5=10800000 tons = 10.8 million tons

At 20% = 2160000 tons = 2.16 million tons

Patch 2:

750×250×96×2.5=45000000 tons = 45 million tons

At 20% = 9000000 tons = 9 million tons

Patch 3:

700×200×91×2.5 = 31850000 = 31.85 million tons

At 20% = 6370000 tons = 6.27 million tons

Potential Proved Reserves = 17.53 million tons
(Patch 1, 2 & 3)

Floats of Limestone = 10,000 tons

Resources (Probable & Possible) = 70.12 million tons,
Total Resources = 87.65 million tons

These data showed that the Ketketo block's limestone deposits have commercial value in terms of its suitability in industries like steel and cement. In steel industry this limestone can be utilized as a flux and in cement industry it can be utilized as a raw material for making clinker.

Conclusions

Our study showed that remote sensing is a very useful low cost technique which served our purpose in regional exploration of limestone. Just in the initial phase of regional exploration three patches having good resource potential and quality of limestone were demarcated in the block. The analyzed samples of limestone showed good quality

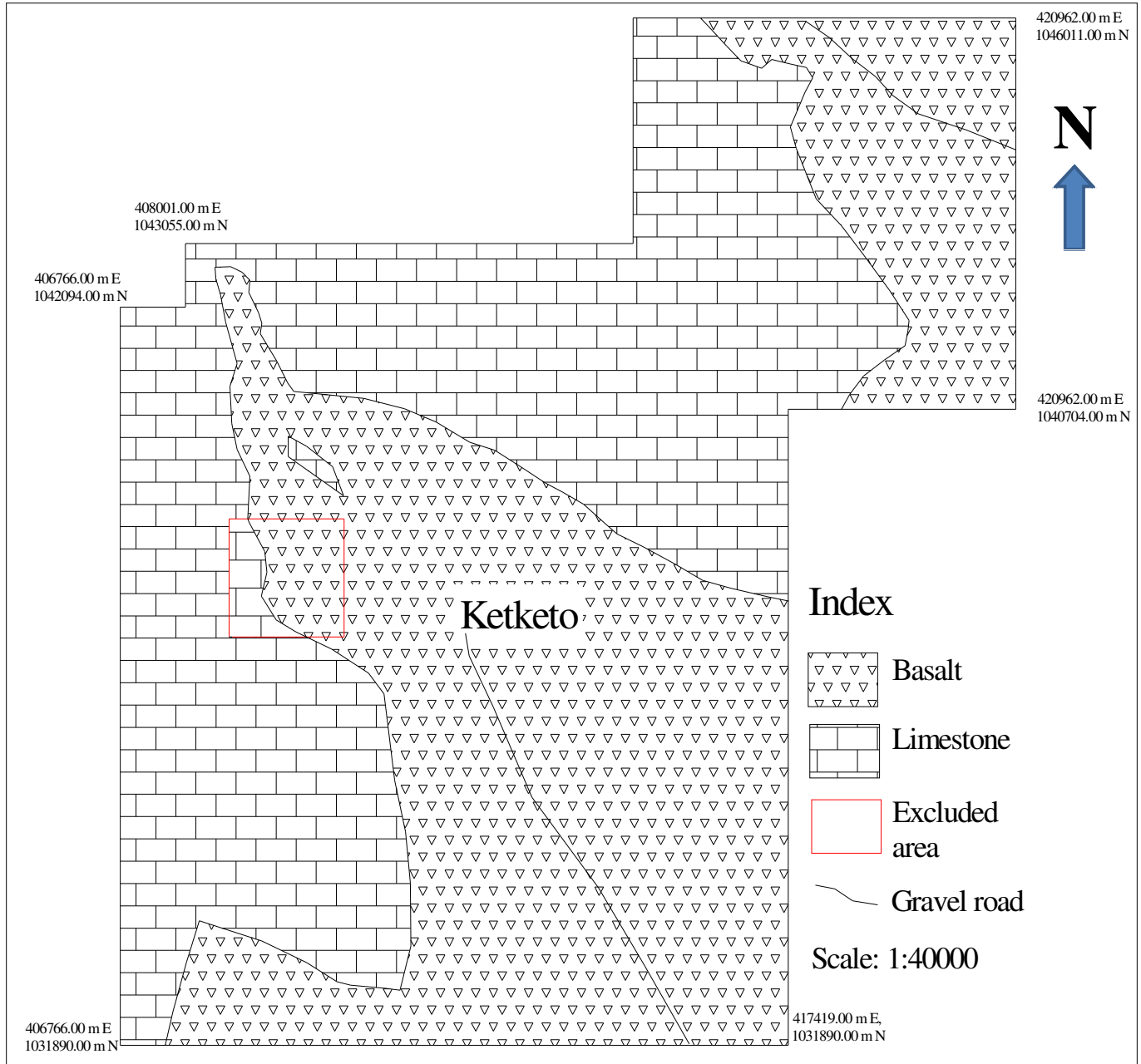


Fig. 3. Surface geological map of Ketketo block.

(CaO% – 50.74 - 55.14, SiO₂% – 0.17 - 4.73, MgO% – 0.06 - 0.80, sulfur, phosphorus, iron oxide and alumina within 1%). The quality of limestone suggests that it can be utilized for manufacturing of steel and cement. The quality based reserves estimation indicated about 17.53 million tons of limestones in proved category within 20 meter

depth from the surface. Geology guided remote sensing based exploration approaches led quite fast exploration works in the block with success in the discovery of good quantity and quality limestone, at relatively low exploration cost, within very short time duration.

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